

NEW EXPERIMENTS ON ALKALI SOIL
TREATMENT*(Preliminary Report)*

BY

CHARLES B. LIPMAN AND LESLIE T. SHARP

The presence of "alkali," denoting water-soluble salts in considerable quantities in soils, has long been one of the problems of soil management in arid regions from the point of view of the practical as well as that of the scientific man. While soluble salts like magnesium and calcium sulphates, and chlorides as well as, in some cases, nitrates of the alkalies and alkali earths and other soluble compounds frequently occur with them, the salts which usually are found to cause injury in alkali soils are sodium chloride, sodium sulphate, and sodium carbonate. It is unnecessary to go into detail here on the specific effects of every one of these salts. Suffice it to say, that in general the damage is caused by these salts through corrosion of living plant substance, through plasmolysis of plant cells owing to injurious osmotic influences, and through effects on the physical, chemical, and bacteriological constitution of the soil which result in poor aeration, poor moisture supply, improperly balanced chemical composition of the soil solution, and in impairment of those bacteriological activities necessary to insure an available supply of plant food substances, particularly of the nitrogen variety.

Alleviative measures in vogue to date in dealing with the alkali problem as it affects crop production have been, in general, of two classes. The first class is that concerned with the removal of alkali salts from the affected soils by flooding, accompanied by underdrainage by natural or tile drain methods. The second

class has been that of rendering innocuous, in part or in whole, the alkali salts without their removal from the soil. In the latter a division may again be made into methods of chemical treatment, such as that against sodium carbonate, or "black alkali," with gypsum and its transformation into the less harmful Glauber salt or sodium sulphate, and methods of heavy irrigation and deep tillage for the purpose of disseminating the salts through a larger internal soil surface, thus rendering less concentrated the soil solution of alkali salts. It may be added in this connection that empirical methods of alkali soil treatment, such as those of Symmonds¹ and Darnell-Smith² in applying nitric and sulphuric acids respectively, and those of others employing barnyard manure, have in a few instances been rewarded with good results. Fuller details with reference to these experiments need not be given here, since they will be discussed in the more complete report which will appear when our experiments have matured.

BASIS OF THE PRESENT EXPERIMENTS

It will be noted above that ameliorative measures in alkali land treatment have been, with the exception of that of the drainage treatment and that of the Hilgard proposal of gypsum treatment against black alkali, of an empirical nature and not based on established scientific principles. Some measures have indeed been employed without any good reason. It occurred to the writers, therefore, to attack the problem of alkali treatment in soils on the scientific basis of principles established on theoretical or experimental grounds. The latter included, broadly speaking, the principle of antagonism between ions,³ and those of the behavior of soil colloids and chemical soil constituents in the presence of soluble salts, or on the removal of soluble salts.⁴

¹ Journ. Agr. Gov. New South Wales, vol. 21 (1910), p. 257.

² Rept. Govt. Bur. Microbiol. New South Wales, vol. 2, p. 209.

³ See papers of Osterhout in *University of California Publications in Botany* and those of C. B. Lipman in *Centralblatt für Bakteriologie*, 2^{te} Abt.; also paper soon to appear by C. B. Lipman and W. F. Gericke, in *Journal of Agricultural Research*.

⁴ In detailed studies carried out by L. T. Sharp, which are soon to be published, many data of a fundamental nature have been obtained, on the importance of the relationship existing between soil colloids and soluble salts, particularly when the latter are leached from a soil.

Since the first-named principle is supported by numerous experiments demonstrating the efficacy of some salts in preventing the toxicity of others to plants and to soil bacteria, we have attempted to approach the production of a more balanced soil solution by treating the affected soil with certain salts. Since likewise the experiments of one of us above cited have demonstrated the harmful effects on the soil colloids of the washing out of salts as well as on the removal of necessary elements in the soil, we have attempted to prevent such harmful effects or to neutralize them by the methods of acid and manure treatment which we have employed. The details of our experiments follow below.

THE METHOD OF THE EXPERIMENTS

A large quantity of alkali soil was shipped to the greenhouse from a field south of Kerman in the San Joaquin Valley. This soil, which had been previously analyzed for alkali, was found to contain 0.64 per cent of water-soluble salts which was composed as follows: 0.459 per cent NaCl, 0.098 per cent Na_2SO_4 , 0.083 per cent Na_2CO_3 . It is understood, of course, that the determinations just given are according to conventional analytical methods made referable to sodium as the base, whereas of course other bases must usually occur as above intimated along with the acids determined. In this case, however, only traces of calcium and magnesium were found. The soil just described has never been cropped and has borne only a sparse vegetation of plants resistant to alkali and drouth. It was distributed in eight-inch earthenware pots in portions of six kilograms each and the pots received the following treatments:

- Nos. 1, 2 and 3— Untreated.
- Nos. 4 and 5— 30.42 gr. each of actual H_2SO_4 c.p.
- Nos. 6 and 7— 41.76 gr. of actual H_2SO_4 c.p.
- Nos. 8 and 9— 11.02 gr. each of actual H_2SO_4 c.p.
- Nos. 10 and 11— 62.08 gr. each of actual $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ c.p.
- Nos. 12 and 13— 6.00 gr. each of actual CuSO_4 c.p. calculated as anhydrous salt.
- Nos. 14 and 15— 30.00 gr. each of actual FeSO_4 c.p. calculated as anhydrous salt.
- Nos. 16 and 17— 12.00 gr. each of actual Na_2SO_4 c.p. (anhydrous).
- Nos. 18 and 19— 300.00 gr. each of actual air-dry barnyard manure.

About three days after these treatments were given, selected barley seeds of the Beldi variety were planted in all the pots to the number of thirteen in each. They were later thinned to four plants for each pot. As nearly as possible, optimum moisture conditions were maintained in all the pots throughout the experiment and caution was observed in irrigation so as to obviate any possibility of percolation and the inevitable leaching of salts which would accompany it.

RESULTS OF THE EXPERIMENT

The seeds were planted on August 2, 1914, and the crop harvested on January 23, 1915. The following table gives the data regarding yields obtained.

TABLE I
YIELDS OF BARLEY OBTAINED IN ALKALI SOIL TREATMENT

No. of pot	Yield of tops grams	Yield of roots grams	Yield of grain grams	Increased weight of tops over control avg. grams
1	.8	.5	.00	
2	5.5	1.2	.05	
3	8.0	1.7	.05	
4	16.8	6.9	.80	12.80
5	17.0	3.9	.70	12.90
6	4.3	1.1	.05	-0.45
7	15.2	3.0	.10	10.50
8	15.8	3.3	2.60	13.60
9	14.5	3.6	2.20	11.90
10	6.7	1.1	1.15	3.05
11	8.2	.8	1.20	4.60
12	.2	--	.00	-4.60
13	.2	.1	.00	-4.60
14	5.3	.5	.00	0.50
15	12.2	8.7	.50	7.90
16	1.7	.6	.00	3.10
17	1.7	.6	.00	3.10
18	10.0	5.2	.90	6.10
19	7.4	3.9	.90	3.50

The marked effects produced by some of the treatments of the alkali soils are clearly indicated in the data submitted in the foregoing table. Of the three control pots, only Nos. 2 and 3 are probably representative of the true conditions in the soil. But, even taking these larger values for the yields of barley obtained from the untreated soil, it is very striking to note the beneficial effects of several of the treatments. This is especially noteworthy in the case of the sulphuric acid treatments and particularly at the smallest application of that acid. The yields in pots 4 and 5 and pots 8 and 9 are more than three times as large as those of the average yield of the two control pots, 2 and 3. The discrepancy between the duplicate pots (6 and 7) of the largest sulphuric acid application cannot definitely be accounted for, but it is obvious that several explanations might be offered therefor. Even the gypsum, ferrous sulphate, and barnyard manure treatments were instrumental in improving very materially the producing power of the soil for barley. Evidence is now in hand which will be published later indicating that ameliorative results may be obtained with ferrous sulphate far superior to those indicated in Table 1 by using less of the salt and by obviating the deleterious effects of the ferrous salt by allowing it to become partially oxidized in the soil before the seed is planted. It will be noted further that CuSO_4 and Na_2SO_4 were without effect in a positive direction and appeared even to render the soil a much poorer medium for the growth of barley than it was before treatment.

When we pass from the total yields of dry matter to those of the grain produced, the smallest of the three sulphuric acid applications employed seems to be far and away the best treatment of all tested. In respect to the grain yield again, gypsum, and not the intermediate sulphuric acid treatment, stands second, and the latter and the manure treatment are about even.

So far as the root yields are concerned, the data are too irregular to allow of our arrival at any definite conclusions. They do not appear to follow in a general way the yield of tops, are more consistent and regular in the sulphuric acid treatments, and best developed in the manure treatments. In general the favorable treatments were productive of more fibrous root-

development and the unfavorable treatments, or the untreated soils, of short, thick roots having very few fibrous roots. The two exceptionally large root yields in pot 4 and pot 15 are not capable of satisfactory explanation at this time.

It is not our purpose to explain at this time in detail the causes underlying the positive or negative effects of the various treatments, since such explanations will appear in the more complete reports of the work which are to follow. It may be said here briefly, however, that the H_2SO_4 exerted its influence, both in the direction of neutralizing the Na_2CO_3 and that of improving the soil's physical condition through its shrinkage of colloids. In smaller measure, likewise, gypsum exerted similar effects and in addition thereto exerted the characteristically strong antagonistic effect to the sodium and acid ions which calcium is known to exert in the plant world. The effects of FeSO_4 are to be explained in general as are those of CaSO_4 . The effect of the barnyard manure is probably exerted through the organic colloids produced in its decomposition, which through the enormous surface they possess hold much of the salts or components of the latter in a condition which prevents their ready solution in the soil water. Moreover, the organic colloids render the soil more retentive of moisture, therefore diluting the soil solution, and besides exert the most marked effects of any of the materials used in the improvement of physical conditions in the soil. Many other effects are probably also involved in the manure treatment which, like those above mentioned, cannot be discussed here.

Detailed studies are now being made of a chemical, physical and biological nature to determine, so far as may be, the intimate effects concerned in treatments of the soil which are above outlined. Much material has already been accumulated from these supplementary studies which is of great practical as well as theoretical significance.

No less interesting and striking than the data given in Table 1 is the series of photographs accompanying this paper. These confirm in the appearance of the plant growth what is so clearly shown in the record of yields as above discussed, and the reader's attention is particularly directed to them.

OTHER EXPERIMENTS

In addition to the experiment above discussed, we have now in progress another pot experiment similar to the first, and several field experiments. In the new pot experiment a different soil, coming from Kearney Park near Fresno, is being employed. This soil contains only about 0.44 per cent total salts based on the dry weight of the soil. The total alkali is differently distributed than in the soil of the foregoing experiment, consisting of 0.18 per cent Na_2CO_3 , 0.16 per cent NaCl and 0.10 per cent Na_2SO_4 . It may be stated, briefly, with respect to this experiment that even more striking results are already manifest than in the foregoing series. Nevertheless, it must be added that the barley plants are only six or seven inches high as yet and any predictions as to the final outcome of the experiment would be premature. It is interesting to note, however, that to date none of the control pots shows any growth worth mentioning and that in the treated pots there is better agreement than in the preceding series so far as duplicate pots are concerned.

Of the field experiments above referred to we have five different locations in the San Joaquin Valley, all in the vicinity of Fresno. These consist of small treated and untreated plots in the open alkali fields. Four of the plot experiments concern the growth of barley, while the fifth concerns alfalfa. It is far too early to predict anything as to the outcome of these field experiments, since the period of growth is just beginning, but we have already made observations on one set of plots which gives hopes for success.

GENERAL REMARKS⁵

The brief statement above made is here submitted to call attention to some striking results already obtained and to the promise of new ones to which present experiments are pointing.

⁵ Since writing the preliminary statement above given the writers have found that owing to too slight a covering of paraffine on the inner walls of the pots some of the salts were absorbed by the porous clay. This can be of little significance only in connection with our statement however, since the largest amounts of salts remain in the pots which gave the heaviest yields. We only advert to the circumstances here for more completeness of record and for future reference.

Obviously the practical significance of any such experiments in the event of their proving successful would be very great. The vast areas of alkali land in this state which at present are worthless could be made to increase California's wealth enormously if they can be treated so as to make them produce, and particularly if they can be treated cheaply. If our experiments should turn out to be entirely successful, as we now have good reason to think they will, treatment of alkali land as outlined above to make it profitable, should prove, relatively, to all other methods, by far the cheapest method of reclamation.

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ERRATUM

The plates have been misplaced. Plate 1 has been printed as Plate 3, Plate 2 as Plate 1, and Plate 3 as Plate 2. Plate 4 is correctly placed.

The pots have not been numbered. They are arranged in order from left to right; thus, on Plate 1 (printed as Plate 3) are pots 1 to 5; on Plate 2 (printed as Plate 1) are pots 6 to 10, etc.

EXPLANATION OF PLATES

PLATE 1

Treatment of Pots reading from left to right

Pots 1, 2 and 3. No treatment.

Pots 4 and 5. 30.42 grams each of actual H_2SO_4 .



PLATE 2

Treatment of Pots reading from left to right

Pots 6 and 7. 41.76 grams each of actual H_2SO_4 .

Pots 8 and 9. 11.02 grams each of actual H_2SO_4 .

Pot 10. 62.08 grams of $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$.



PLATE 3

Treatment of Pots reading from left to right

Pot 11. 62.08 grams of $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$.

Pots 12 and 13. 6.00 grams each of CuSO_4 as anhydrous salt.

Pots 14 and 15. 30.00 grams each of FeSO_4 as anhydrous salt.



PLATE 4

Treatment of Pots reading from left to right

Pots 16 and 17. 12.00 grams each of Na_2SO_4 anhydrous.

Pots 18 and 19. 300.00 grams each of air-dry barnyard manure.



